Hovercraft Based Farming system

Aneesh H. Nair[1], Krishnanand P. Pai[2], Mathews Varghese[3], Sunil Baily Thomas[4], George T.S[5]
[12345]DepartmentOf Mechanical Engineering ,Saintgits College of Engineering, Kerala.
E mail: - [1]aneeshh.nair@yahoo.com, [2]krishnanandppai@gmail.com,[3] mathewsvarghese00@gmail.com, [4]sunilbailysbt@gmail.com, [5]george.ts@saintgits.org

Abstract-Agriculture and allied sectors are the most crucial sectors of the Kerala Economy. In that paddy cultivation plays an important role, being the staple food of Kerala. With the drop in production of paddy due to various reasons, the state of Kerala has to depend heavily on the neighbouring states for the same. Reduction in cultivated land, labour shortage, unscientific and out-dated methods is some of the causes for this situation in paddy cultivation. Based on the interaction with farmers, various agricultural officers and NGOs, it was identified that the farmers are facing a huge problem of labour scarcity.

One key area which results in huge losses in terms of money and paddy seeds is sowing. Hence a remote controlled device was developed, which can do the sowing of seeds with correct spacing (thus avoiding transplanting), weeding and spraying fertilizers while being controlled by a single person. Thereby no additional workers are required to perform these tasks. By changing the type of container used, or by using a weeding attachment, the device can be used for sowing, weeding and spraying fertilizers, thereby greatly reducing the time taken and the cost involved in paddy field cultivation.

Keywords – Hovercraft, farming, control systems

I.INTRODUCTION

Paddy is one of the important crops in the World. It is a major staple food and is vital for the nutrition of much of the population in Asia, as well as in Latin America and the Caribbean and in Africa. Developing countries account for 95 percent of the total production, with China and India alone responsible for nearly half of the world output [1]. For about 65% of the people living in India, paddy is a staple food for them; therefore, paddy is essential to life in India. It is a part of nearly every meal, and it is grown on a majority of the rural farms [2].

Paddy fields are common sight across India. Paddy is cultivated at least twice a year in most parts of India, the two seasons being known as Rabi and Kharif respectively. The former cultivation is dependent on irrigation, while the latter depends on Monsoon. In agriculture sector women play an important role by contributing as active labor workforce. In India women carry out as much as 80 percent of the work in paddy production [3]. They are involved right from seeding, transplanting, weeding, harvesting etc.

After the interaction with the farmers, agricultural officers, researchers and media persons, the various causes that result in the decreasing production rate of rice in Kuttanad were identified as,

- Labor shortage
- Traditional methods used for sowing.
- Rising costs due to reduced profits and unscientific methods.
- Machines used are not designed for the soil conditions of Kuttanad.
- Reduced yield due to skipping of processes like leveling, improper spacing.

A survey was conducted to get feedback on the design and to know whether the farmers will buy such a device. About 16 farmers were shown the design, and it was identified that almost every farmer is facing the problem of labor scarcity. Out of the 16 farmers/land owners we spoke to, 7 of them still continue farming on their field, 11 of them have leased their land and 5 of them have stopped farming on their land due to various reasons varying from labor scarcity, reduced profits, and water scarcity and even because of moving away. But about 3 farmers even though they have stopped farming are interested to do it again, if there is labor availability and increased profits. Majority of them were interested in the idea of the product, and they wanted to try out the device in real to give more feedback. But 3-4 farmers were more skeptical on the design and they preferred to go with the traditional methods.

A. *Farming processes*

The device will be able to perform sowing, weeding and fertilizer dispensation. The current method of doing sowing is, by tossing up the seeds on to the field by a labor/farmer who walks around the whole field. Soft soil conditions mean that the farmer’s legs sink into the mud and makes movement through the field difficult [4]. Since the seeds are not sown with the correct spacing, the saplings are to be plucked out from the field and replanted again with the correct spacing (this process is called Transplanting). Weeding is the process of removal of weeds, by plucking out

the weeds manually or by means of mechanized devices which cut out the weeds.

B. *Problem statement* and background

After analyzing the data obtained from the farmers, Agricultural officers, Media persons etc. We came to the conclusion that many farmers in Kuttanad are facing a major inadequacy of labor. Unavailability of workers for the farming processes, a remote controlled device which is controlled by a single farmer addresses this problem. Labor cost is high, and still increasing. 600 Rupees and 300 Rupees for Male and Female labor respectively per day makes the farmer's profit margins even lesser. Inefficiency involved in the traditional farming processes and methods means that the workers have to work long hours. Many land owners are giving up farming due to these increasing costs. Labor wages is the biggest contributor to the costs. Major challenge is to sow seeds with the correct spacing between them.

II. METHODOLOGY

In the paddy fields of Kuttanad, which is one of the only two places in the world where agriculture is done below sea level, the soil condition is very soft and the sinkage is very high.Moving through this soft soil is very difficult even for a single farmer, thus pulling or pushing a device through the field is even hectic and hard task. This is the reason why we thought of using a hovercraft to carry the farming mechanism over the field, so that the hovercraft can hover over the ground easily and a remote control to control the farming mechanism means that the farmer does not even have to step into the field. He can just stay at the side of the field, on the boundary and control the hovercraft and the farming mechanism through the remote.

The benefit of this hovercraft idea is that now, the work done by the farmer is tremendously reduced, all he has to do is control the craft through the remote and make sure that the device is moving in straight lines, and just ensuring that the farming happens in the required manner. This means that the energy expended by the farmer is greatly reduced and thereby the area that can be covered by the farmer in a single day is far more than that can be covered in the conventional method. This is because the farmer needs to take no or very few breaks as he is not required to do any work than controlling the device.

B. Hovercraft principle

The hovercraft floats above the ground surface on a cushion of air supplied by the lift fan. The air cushion makes the hovercraft essentially frictionless. Air is blown into the skirt through a hole by the blower.The skirt inflates and the increasing air pressure acts on the base of the hull thereby pushing up (lifting) the unit. Small holes made underneath the skirt prevent it from bursting and provide the cushion of air needed. A little effort on the hovercraft propels it in the direction of the push. Fig 1 shows how the pressure is developed in the skirt [5].

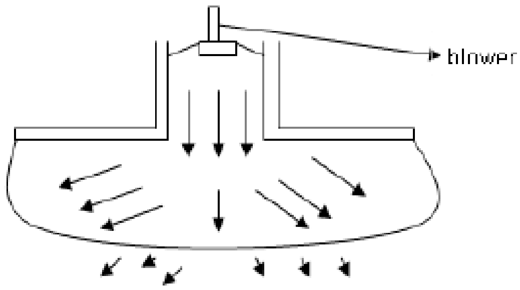

Fig. 1 Pressure development in the skirt

III.DESIGN PROCESS

After analyzing the feedback from the farmers, an initial design was articulated as a result of brainstorming and after each design phase, the design was shown to the farmers and feedbacks were taken. Considering the feedbacks obtained and the opinions from the farmers and as result of technical analysis, modifications were made on the design. Thus there were three design phases.

A. Initial Design

Initial design was a circular platform with the sowing mechanism mounted at the back of the lift blower. The circular platform had to be replaced with a rectangular shaped platform so that the drums can be placed easily and also the placing of the seeds could be better done in a rectangular platform. The skirt material was thought to be plastic or vinyl so that it has the strength to withstand the air pressure inside the skirt and also can withstand the watery conditions of the paddy field.

The platform material was to be aluminium plate. The blower was placed at the center and the thrust fan was placed behind it. The seed container was placed below the thrust fan so that the air from the fan wouldn't affect the seed movement and placing. A slanting plate with grooves was also added to the design which would provide a slope for the easy movement of the seeds to the paddy field.

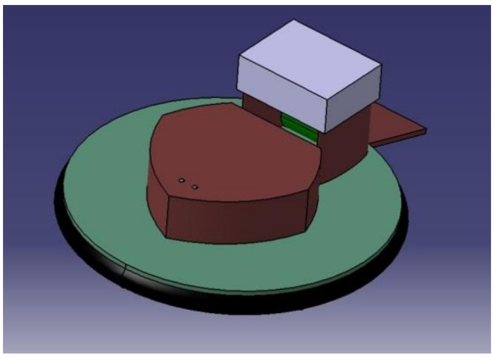

Fig. 2 CAD model of initial design

B. Second Design

The platform was made rectangular with an arc at the front. The proposed length of the platform was 1 meter and the width about 60 Centimeters, considering the placement of the seed

containers. Two seed containers were placed behind the lift blower. The drums were placed below the thrust fans. The skirt materials were same as the first design and the platform material was also Aluminium.
The metering is done by a motor, which rotates the seed container drum at the correct speed to get the required spacing between the seeds. The motor used is a low speed gear motor to rotate the drum and is controlled by the remote.

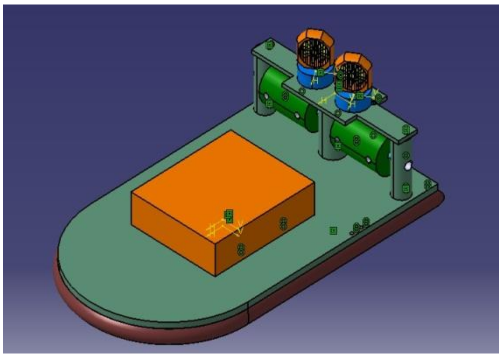
Fig. 3 CAD model of second design

C. Final Design

The final design is similar to the previous ones as it uses the same skirt material, platform material etc. The placement of the blower remains unchanged as for the thrust fans. The platform design of the thrust fan was modified by using iron bars so as to reduce weight when compared to bigger heavier iron cylinders in the previous designs.

- The Blower used is an AC motor of 50W and with a maximum rpm of 13,000.
- The thrust fan used was a DC fan with the blades from a exhaust-fan.
- The DC battery to power the thrust fan is also mounted on the device.
- The seed container is made of plastic, which is light-weight and also less affected by water.
- The platform to place the seed container is also made of aluminum.
- The wheels used to measure the displacement of the device is also made of plastic

D. Fabrication

The third design was shown to farmers and feedbacks were taken. But many farmers didn't clearly understand the device and how it would function. They couldn't answer questions about whether they will buy such a device due to the same reason. They wanted to see a model and test it by themselves to give their opinions. Thus a model was fabricated to demonstrate to the farmers on how the device will function.


Fig. 4 Photograph of the prototype

A scaled model was made. The material specifications are mentioned below. The hovercraft was fabricated first and the sowing, weeding and fertilization dispensing mechanisms mounted on it. The device is controlled by a remote control, the receiving, transmitting, relay circuits are also mounted on the hovercraft. A photograph of the final prototype is shown below.

IV.CALCULATIONS

Lift and thrust required to lift the hovercraft and to facilitate its movement through the field is to be calculated. Which gives an idea on which blower has to be chosen. The calculations performed are as shown below.

Calculations on drum designs were also done and the numbers of slots for various drum diameters are as shown below. An experiment which shows the relationship between the seed flow rate and the length of the drum is also shown. The relevance of this experiment is that, it shows as the length of the seed container drum increases, the seed flow increases. This result is made use of the final design.

A. Lift calculations

A hovercraft will float when the air pressure beneath it, contained within its skirt, is great enough to support its weight. Using Bernoulli's equation, it's possible to calculate the volumetric flow rate of a hovercraft fan necessary for the vehicle to hover, based on its dimensions and its mass. The calculations are as shown below.

Consider the figure shown below, the vertical forces acting on a hovercraft of mass M, include gravitational force Mg, force due to air pressure P_{int} acting on surface area beneath the hovercraft and force due to air at atmospheric pressure pushing down on the top surface of the hovercraft. Viscous forces are assumed negligible.

Let,

h= Clearance of the height.
l = Length of the hovercraft.
M= Mass of the hovercraft.

Net vertical orce, $\Sigma F_y = -Mg + P_{int}A_{bottom} - P_{atm}A_{top}$.
Internal pressure, $\mathbf{P_{int} = P_{atm} + (Mg/A_{bottom})}$.

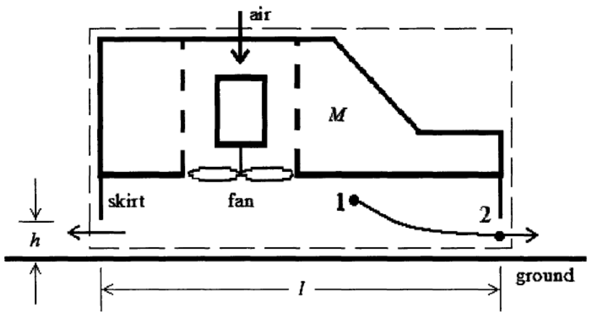

Fig. 5 Schematic diagram of a hovercraft and its lift development

Assume, $P_{int} = P_1$.
$(P_1/\rho) = (P_{atm}/\rho) + (V_2^2/\rho)$.
where $V_2 = \sqrt{\frac{2}{\rho}\frac{Mg}{A}}$
So volumetric flow rate,

$$\mathbf{V = V_2.\ 2(\mathit{l} + w)h = 2(\mathit{l} + w)h\sqrt{\frac{2}{\rho}\frac{Mg}{A}}}$$

Put, l = 1m, h = 0.001m, w = 0.6 m, M = 6 kg, ρ = 1.2 kg/m^3.
$\dot{V}=2(1+0.6)0.001\sqrt{(\frac{(2x6x9.8)}{(1.2x0.6)})}$
V = 0.038 m^3/sec.

Thus, the volumetric flow rate required to lift the hovercraft is obtained. A blower which can give this flow rate is what is required to lift the hovercraft. Thus we choose a blower which could provide us 2.5 m^3/min volume flow rate as per the manufacturer's specifications when running at full speed.

B. Thrust calculations

To calculate the thrust that has to be provided by the thrust fans to facilitate the motion and maneuvering of the hovercraft, it is necessary to calculate the thrust required to select the sufficient fan to provide the thrust. The calculations to find the thrust required, based on the size of the hovercraft are as shown below.

We have,
$T_g = Q_d x V_d$ x ρ.
Where,
T_g = Gross thrust.
Q_d = Quantity of air at discharge.
V_d = Discharge velocity.
ρ = Density.
Let, Momentum drag be D_m.
$D_m = Q_d$ x V_0 x ρ.
Where, V_0 = Free stream velocity.
Net thrust, $T_n = T_g - D_m$.
$T_n = Q_d$ x ρ x $(V_d - V_0)$.

Let,
The density of air is ρ= 1.2 kg/m^3
Diameter of fan blade= 0.23m.
Fan area, A= 0.0415 m^2.
Velocity of discharge V_d= 28 m/s.

Assuming stream line velocity V_0 is negligble.
Thrust force, T_n= 0.0415^{2}x 28x1.2= 0.058N.

Thus the thrust required is calculated as shown above. We have used a high rpm (7000 RPM) AC motor as the thrust fan which was able to give the required thrust under experimental conditions.

C. Drum design

The drum design can be modified to accommodate more slots on its circumference, providing more seed flow. Also, the slot position along the circumference also is a factor which determines the seed spacing along the line of motion of the device. The slot spacing can be varied as shown below, the number of slots and the corresponding radius of the drum required in each case is calculated below.

Fig. 6 Slots on the drum

So,$\mathbf{2\pi r/n}$ **= 10 cm**
Where, *n= number of slots, r= radius of drum*
So when n= 1, r= 1.6 cm
n= 2, r= 3.2 cm
n= 3, r= 4.8 cm
n= 4, r= 6.4 cm

D. Rotational speed and seed flow

Sowing the paddy seeds with the correct spacing is very crucial and there are various factors that affect the proper placement of the seeds on the field. An experiment is explained below to understand the relationship between the Rotational speed of the seeder and the seed flow rate (number of seeds coming out of the seeder per minute). This study was carried out at the Department of Agricultural Engineering, Rice Research Institute of Iran (RRII), Rasht, Iran. Schematic representation of the seeder unit used in the experiment is shown.

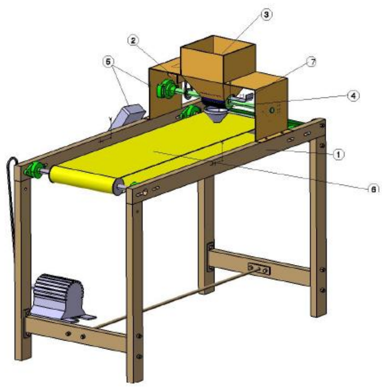

Fig. 7 Schematic representation of the experiment unit

The test apparatus comprised of (1) chassis, (2) electric motor, (3) seed hopper, (4) fluted-roll seed metering device, (5) rotational speed controller, (6) conveying belt, (7) discharge gate. The paddy seeds were cleaned to remove all foreign matters and broken seeds. To prepare the pre-germinated paddy seeds, the unfilled grains were separated by using solution of water and salt. The filled paddy seeds soaked into fresh water for 48 hours, and then the samples were poured into separate polyethylene bags and were kept in temperature of 27-30°C for starting the germination process. After the germination completed, the samples kept in the refrigerator. Before starting a test, the required quantity of pre-germinated seeds was taken out of the refrigerator and allowed to warm up to room temperature [8].

In each test run, the hopper of the seeder unit was filled with the pre-germinated paddy seeds. The rotational speed of the metering device was controlled by using a motor DC 24V-1.5A. DC motor can rotate in the different speeds through rotational speed control. A counter sensor was installed on the distributor's axis. This sensor was composed of two infrared transmitter and receiver diodes and circle grooved sheet between these two diodes. With rotation of distributor's axis, information produced from rotation of axis was given to rotational speed control device and finally actions of comparison and control of distributor's rotational speed with received rotational speed by user was down inside of rotational speed control circuit.

Speed control circuit: The variation of the seed flow rate according to the change in length of the seeder and rotational speed were noted. And the graph is plotted.

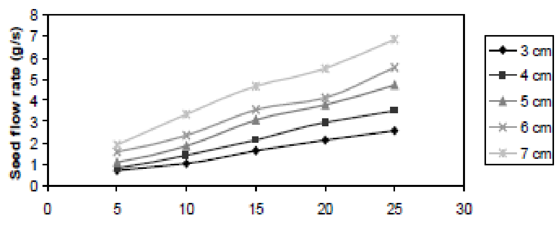

Fig. 8 Rotational Speed vs. Seed flow

From the experiment, it can be seen that as the length of the seeder increases, there is more seed flow rate.

V. RESULTS AND DISCUSSION

Testing was conducted by filling the seed container with half its capacity. The device was made to move a distance of 5 meters on a level floor to simulate the seeding process. The device had to in a straight line so that the correct spacing could be achieved between seeds. During testing, the device showed a tendency to move sideward (towards left). This was due to the slight inclination of the thrust fan duct, to the left. This inclination was corrected and tested again, which yielded positive results. The seed drum was rotated by the motor and seeds were discharged on to the ground with approximately the required spacing. The device was remote controlled throughout the operation.

The device will help the farmers to sow seeds uniformly and efficiently and the device also makes the task less difficult for the farmers. Additional replaceable and user friendly attachments can convert the device into a weeder; which can remove any weeds present in the vicinity of the paddy as well as into a fertilizing device; which can efficiently and effectively sprinkle the fertilizer on to the paddy field.

VI. CONCLUSION

The design and fabrication of 'Hovercraft based farming system' was successfully done and the results obtained shows that the device can be used conveniently in the paddy field. In this work, the blower available in the market was used which was best suited for our prototype. For future scaled up applications correspondingly higher power blowers as well as thrust fans will be used. This will be governed by the equations that were used to calculate the lift and thrust as well as the prevailing conditions in the paddy field. After analyzing, the stresses and strains that occur in the aluminium sheet were estimated using Solidworks and it was inferred that the design is safe.

The scaled up prototype will house a mobile power source and make the design completely wireless. The plan involves mounting a battery and inverter on the hovercraft which will make the device independent of the power supply and it can move over the field without any limitations and need of power supply wire. The future designs will also able to perform harvesting. Also the device will be integrated with a line following robotic system which will allow the design to become fully automated rather than the present one which is semi-automated. This device will follow a programmed path and will do the operations as specified by the program.

REFERENCES

[1] Sucheta Singh, Oliver Hensel, On Farm Reearch (OFR) on Transplanting Paddy: A "Best-Bet" Prototype for Drudgery Reduction, International Journal of Agriculture, ISSN 2228-7973, 2012.

[2] R.Vijay, K.V.N.Rakesh, B.Varun, Design of a Multi-Purpose Seed Sower Cum Plougher, International Journal

of Emerging Technology and Advanced Engineering, Volume 3, ISSN 2250-2459 ,2013.

[3] Ali Dabbaghi, JafarMassah, MohammadrezaAlizadeh, Effect of Rotational Speed and Length of the Fluted-Roll Seed Metering Device on the Performance of Pre-germinated Paddy Seeder Unit, Internatıonal Journal of Natural and Engineering Sciences 4, ISSN: 1307-1149, 2010.

[4] Sheeja K Raj, Nimmy Jose, Reena Mathew, Leenakumary S, Influence of Stand Establishment Techniques on Yield and Economics of Rice Cultivation in Kuttanad, International Journal of Scientific and Research Publications, Volume 3, ISSN 2250-3153, 2013.

[5] Okafor,B.E, Development of a Hovercraft Prototype ,International Journal Of Engineering And Technology Volume 3 No. 3, March, 2013.

[6] Muhammad ArshadUllah, Syed AleemRaza, Abdul Razzaq and S.D.H. Bokhari, Effect of Planting Techniques (Direct seeding Vs. Transplanting) on Paddy Yield in Salt-affected Soil, International journal of agriculture & biology, 2007.

[7] S.O. Oghalo, Effect of Population Density on the Performance of Upland rice (*oryza sativa*) in a Forest-Savanna Transition Zone, International Journal of Sustainable Agriculture, ISSN 2079-2107 , 2011.

[8] P.P. SHELKE, Frontline Demonstration on Bullock-Drawn Planter Enhances Yield of Soyabean Crop, International Journal of Farm Sciences, 123-128, 2011.